Air Quality Monitoring:

In the Area of **Hardisty** Bulk Petroleum Storage Terminals, **Apache Battle River** and **Signalta Forestburg** Sour Gas Plants

October 2005 and March 2006 **Final Report**

Overview

Alberta Environment conducted ambient air monitoring in the area of the Hardisty Bulk Petroleum Storage Terminals. In the absence of petroleum loading/unloading, concentrations measured downwind of the storage terminal was comparable to rural environments. Elevated concentrations of hydrocarbons, nitric oxide (NO), nitrogen dioxide (NO_2) and particulate matter were measured downwind of one of the bulk petroleum storage terminals at a time petroleum loading/unloading was taking place. Elevated hydrocarbons at this location are likely due to fugitive emissions during loading/unloading of petroleum. Exhaust from trucks used to transport petroleum is likely the main source of NO and NO_2 at this site. Re-suspended road and soil dust as well as vehicle exhaust likely contributed to elevated particulate matter. Alberta has a one-hour objective for NO_2. The maximum one-hour average NO_2 concentration downwind of Hardisty storage terminal was 3% of Alberta's air quality objective.

Air quality monitoring downwind of Apache Canada was conducted in the fall and spring. Sulphur compounds were notably higher in the spring. The results indicate that elevated sulphur dioxide (SO_2) and hydrogen sulphide (H_2S) concentrations were likely due to industrial emissions. The maximum one-hour SO_2 and H_2S concentrations were 3% and 80% of Alberta's one-hour air quality objectives, respectively.

The one-hour average SO_2 concentration of 0.089 ppm measured downwind of Signalta Resources was the highest measured for recent MAML surveys. This one-hour concentration was 52% of Alberta's air quality objective. Elevated NO and NO_2 concentrations were also measured at this site. The maximum one-hour average NO_2 concentration was 4% of the air quality objective.

Alberta
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Introduction

Alberta Environment conducted air quality monitoring at three locations in central Alberta. Monitoring was conducted using Alberta Environment's Mobile Air Quality Monitoring Laboratory (MAML). The MAML is used to routinely perform such unannounced surveys. The surveys discussed in this report were largely conducted in October of 2005 with a supplementary survey in March of 2006. Monitoring was conducted in the vicinity of Hardisty bulk petroleum storage terminal and two sour gas plants: Apache Canada Ltd. in Battle River and Signalta Resources Ltd. in Forestburg. These short-term studies provide a "snap shot" of the air quality in time and space. Data collected may also be used to initiate a more extensive study.

Within the vicinity of Hardisty, eight different companies operate bulk petroleum storage terminals. Petroleum is transported in and out of the area via pipeline, truck or rail. The monitoring objective in this area is to assess the air quality in the area of the Hardisty bulk petroleum storage terminals. The sample period included a time when petroleum loading/unloading was taking place at one of the facilities. This allowed the examination of potential fugitive emissions during such an operation.

Air quality monitoring downwind of the two sour gas plants examined levels of sulphur compounds and oxides of nitrogen. Previous ambient monitoring in the vicinity of Apache Canada Ltd. indicated an increase in total sulphation in early spring. During this study, monitoring downwind of the plant was conducted in the fall and spring to further examine the possible increase of sulphur compounds during the spring. The objective of air quality monitoring downwind of the second sour gas plant Signalta Resources Ltd. was to examine levels of sulphur dioxide and nitrogen dioxide.

Monitoring method and location

The MAML is equipped to monitor a number of pollutants simultaneously. Pollutants measured include ammonia, carbon monoxide, oxides of nitrogen, total reduced sulphur, hydrogen sulphide, total hydrocarbons, methane, reactive hydrocarbons, sulphur dioxide, polycyclic aromatic hydrocarbons, total suspended particulate including fine and course particulate. In addition to these pollutants, the MAML also measures the meteorological parameters wind direction and wind speed. Further description of the MAML is found in Appendix B.

The locations of the various monitoring sites are indicated in Figures 1-3 and listed in Table 1. **Sites 1a** and **1b** were located downwind of Hardisty bulk petroleum storage terminal (***Hardisty terminal***). Hardisty terminal provides storage for a number of companies including Hardisty Caverns Limited, Gibson Petroleum Company Limited, Husky Oil Operations Limited, Flint Hills Resources Canada, Cold Lake Pipeline Ltd. (or Interprovincial Pipeline Fund), Enbridge Midstreams Inc and two smaller bulk petroleum storage facilities: Enbridge and Express pipelines. The MAML was positioned at **Site 1a** for periods with southeasterly wind direction. The samplir. location was moved to **Site 1b** when the predominant wind direction became northwesterly.

Measurements downwind of Hardisty Caverns Limited were conducted at **Site 2. Sites 2** and **2a** indicated in Table 1 are at the same location. However, a change in the wind direction during the monitoring period placed **Site 2** upwind of Hardisty Caverns Limited, at which time the location is referred to as **Site 2a**. Data from this period is used as a comparison to concentrations measured when the MAML was downwind of Hardisty Caverns.

Figure 2 illustrates monitoring locations downwind of Apache Canada Ltd.. Monitoring downwind of this gas plant was conducted in the fall (**Site 3a**) and spring (**Site 3b**). The MAML monitored downwind of the second sour gas plant Signalta Resources Ltd. at **Site 4**.

Table 1: List of monitoring sites

Site	Facility
1a	Hardisty Terminal Area
1b	Hardisty Terminal Area
2	Hardisty Terminal Area (downwind of Hardisty Caverns Limited)
2a	Hardisty Terminal Area (upwind of Hardisty Caverns Limited)
3a	Apache Canada Ltd. Battle River sour gas plant (fall)
3b	Apache Canada Ltd. Battle River sour gas plant (spring)
4	Signalta Resources Ltd. Forestburgh sour gas plant

Figure 1: Monitoring locations in the area of Hardisty teminal[1]. Black squares indicate location of buildings and black circles indicate location of above ground petroleum storage tanks.

[1] Base map from Atlas Canada: http://atlas.nrcan.gc.ca/site/index.html

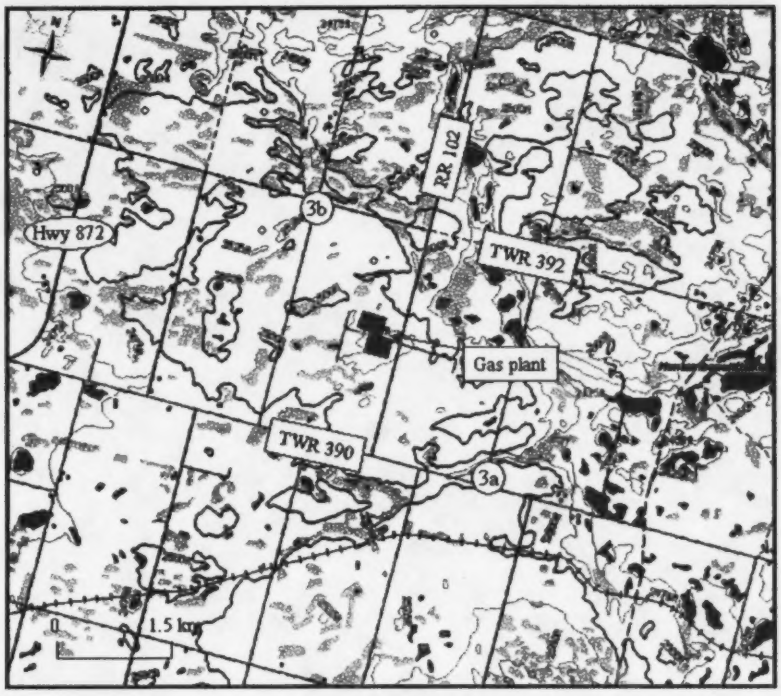

Figure 2: Monitoring locations in the area of Apache Canada Ltd. sour gas plant[1]. Green squares indicate location of Apache Canada Ltd. sour gas plant.

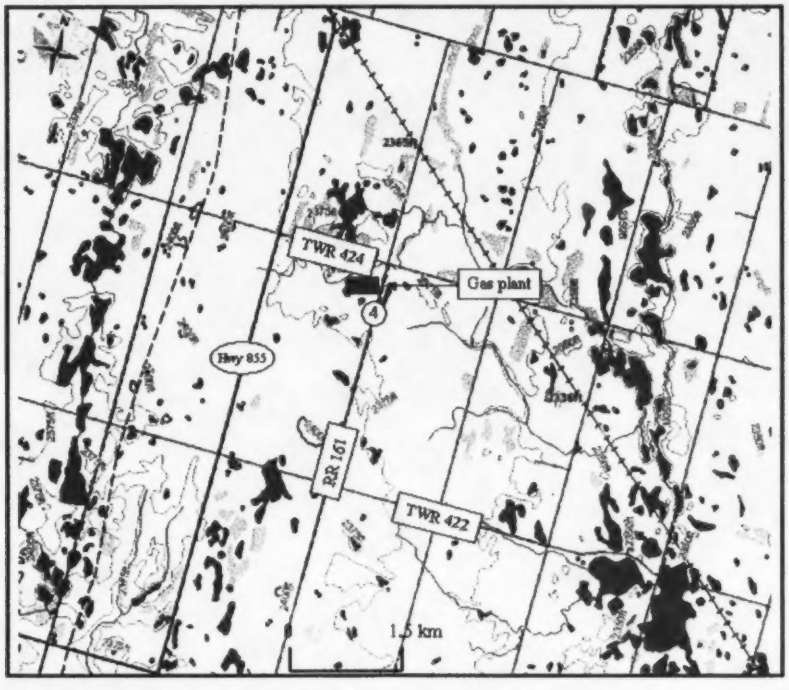

Figure 3: Monitoring location in the area of Signalta Resources Ltd. Forestburg sour gas plant[1]. Green square indicates location of Signalta Resources Ltd. Forestburg sour gas plant.

Results and Discussion

The following sections discuss the pollutant concentrations at the various monitoring sites. The *Result and Discussion* section will focus on those pollutants relevant to the current study. Where available the measured concentrations are compared to Alberta's Ambient Air Quality Objective (AAAQO). A description of AAAQO is given in Appendix B. The one-hour average concentrations for all the monitored pollutants and the site meteorological conditions are presented in Table A1 and A2 in Appendix A. A glossary of the pollutants measured can be found in Appendix B.

Hardisty Bulk Petroleum Storage facility

A majority of the MAML measurements was conducted at **Site 1a** and **Site 1b**[2]. These sites were downwind of a number of the facilities at the storage terminal, namely Husky Oil, Express Pipeline, Cold Lake Pipeline and Gibson Petroleum. There were a total of five sample hours at these two locations. The results are listed in Table 2. One-hour average concentrations did not vary significantly over the sample period. Air quality objectives are available for five of the measured pollutants; none of the AAAQOs were exceeded. Hydrocarbons are the main fugitive emissions from petroleum storage facilities. Concentrations of hydrocarbons as well as oxides of nitrogen, total reduced sulphur and sulphur dioxide were comparable to levels typically measured in rural environments. Petroleum loading/unloading activities were not observed at the time of measurement. ***At the time of measurement*** influence from the storage facility south of Highway 13 (Figure 1) on the surrounding air quality was minimal. Survey results from a 2002 study are also listed in Table 2. At least one of the sample hours during the 2002 study included a time where petroleum loading/unloading was observed. Highlighted in Table 2 are the concentrations of reactive hydrocarbons, oxides of nitrogen, particulate matter and sulphur compounds; these concentrations were relatively higher than concentrations measured during the current study. Higher concentrations of these pollutants during the 2002 study are possibly due to petroleum loading activities.

[2] Recall that **Site 1** had to be moved to **Site 1a** for one of the sample hours due to a change in wind direction.

Table 2: Median and maximum one-hour average concentrations measured downwind of storage tanks (Site 1a and 1b).

Pollutant	Units	2005/2006 Survey		2002[3] Survey		AAAQO
		Median	Maximum	Median	Maximum	
Carbon Monoxide (CO)	ppm	0.1	0.1	0.2	***0.7***	13
Ozone (O_3)	ppm	0.032	0.034	0.039	***0.048***	0.082
Total hydrocarbon (THC)	ppm	2.1	2.1	2.1	2.9	n/a
Methane (CH_4)	ppm	2.0	2.0	1.9	2.2	n/a
Reactive hydrocarbon (RHC)	ppm	0.1	0.2	0.2	***1.0***	n/a
Sulphur dioxide (SO_2)	ppm	0.001	0.002	0.001	***0.005***	0.172
Nitric Oxide (NO)	ppm	0.001	0.002	0.001	***0.010***	n/a
Nitrogen dioxide (NO_2)	ppm	0.002	0.003	0.002	0.005	0.212
Oxides of nitrogen (NO_x)	ppm	0.003	0.004	0.002	***0.013***	n/a
Ammonia (NH_3)	ppm	bd	bd	***0.002***	***0.009***	2
Total reduced sulphur (TRS)	ppm	0.001	0.001	0.001	0.002	n/a
Hydrogen sulphide (H_2S)	ppm	bd	0.001	bd	0.003	0.01
Total suspended particles (TSP)	$\mu g/m^3$	22	80	***140***	***685***	n/a
Course particles (PM_{10})	$\mu g/m^3$	14	49	***82***	***526***	n/a
Fine particles ($PM_{2.5}$)	$\mu g/m^3$	2	5	***12***	***87***	n/a
Polycyclic aromatic hydrocarbons (PAHs)	ng/m^3	bd	1	1	***10***	n/a

Notes
ppm – parts per million $\mu g/m^3$ – micrograms per meter cubed ng/m^3 – nanograms per meter cubed
bd – concentration below the detection limit of the instrument onboard the MAML
n/a – Value not available
Bold and Italic indicates 2002 survey concentrations that were notable higher than the current survey.

The second phase of measurement at Hardisty terminal was conducted at **Site 2** located north of Highway (Hwy) 13. At this site, data was collected over two sample hours. **Site 2** was downwind of Hardisty Caverns Limited for one of the sample hours and upwind of the Caverns for the other. Hardisty Caverns is a facility for storing crude oil underground. As a result the map in Figure 1 does not show above ground storage tanks. At the time start of the sample hour, tracks were loading/unloading on site.

There were significant differences between concentrations measured upwind and downwind of Hardisty Caverns. The results are presented in Figures 4-6. Methane (CH_4) and reactive hydrocarbons (RHC) concentrations downwind of the Caverns were notably higher than concentrations measured upwind. One-hour average concentrations of 3.1 ppm were measured for both CH_4 and RHC. In Alberta, background CH_4 concentration is about 2 ppm; equivalent to the concentration measured upwind. Background concentration for RHC is typically below the

[3] Sample collected on May 22nd ,23rd and 11th

detection limit of the instrument onboard the MAML. Elevated concentrations of hydrocarbons are most likely the result of fugitive emissions during petroleum loading/unloading. Alberta does not have air quality objectives for CH_4 and RHC.

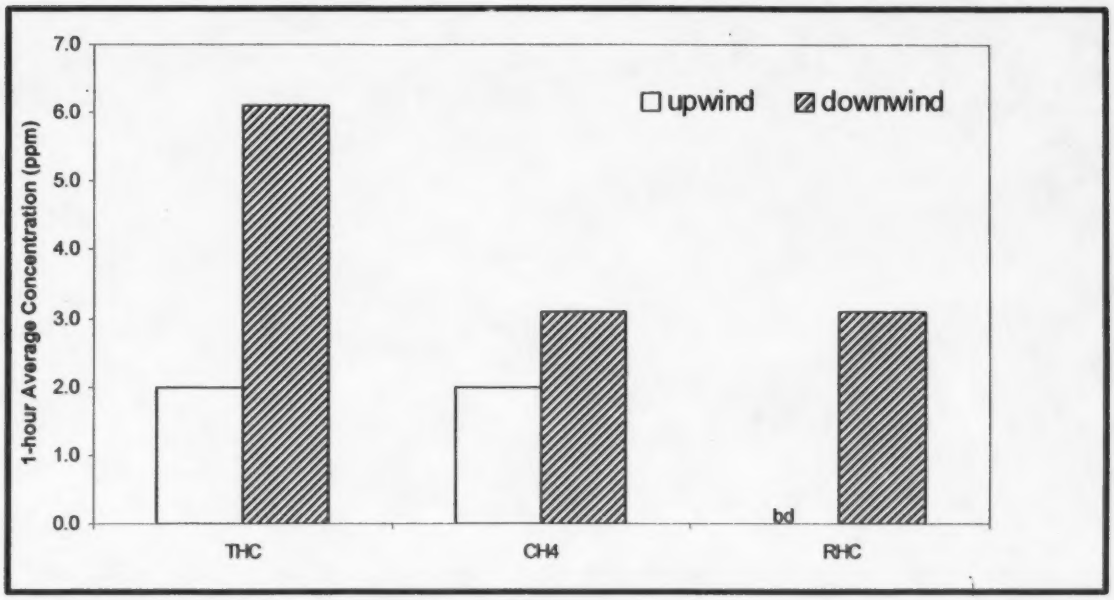

Figure 4: Hydrocarbon concentrations upwind and downwind of Hardisty Caverns Ltd.

Elevated levels of oxides of nitrogen, nitric oxide (NO) and nitrogen dioxide (NO_2), were also noted (Figure 5). The sum of NO and NO_2 is known as oxides of nitrogen (NO_x). NO is produced as a result of high temperature combustion; NO_2 is produced as NO reacts with ozone in the atmosphere. A relatively high NO and NO_2 ratio (0.6) indicates local and relatively fresh emissions. During the sample period, trucks were observed loading/unloading onsite. Truck exhaust is the most likely source of elevated NO_x at this site. The one-hour average NO and NO_2 concentrations were 0.004 and 0.007 ppm, respectively. Truck exhaust probably also contributed to the increased particulate concentrations (Figure 6) with some contribution from re-suspended soil/road dust. The one-hour average total suspended particulate at this site was 96 $\mu g/m^3$. There are no ambient air quality objectives for NO or particulate matter. The objective for NO_2 (0.212 ppm) was not exceeded.

It should be noted that about 20 minutes into the downwind sample hour at **Site 2**, the operation at Hardisty Caverns ceased for the day. At this time, measured concentrations

dramatically decreased (Figures 7 and 8). Thus, the one-hour averages presented in Figures 4-6 may have underestimated the potential one-hour average concentrations downwind of the facility at a time when loading/unloading is ongoing.

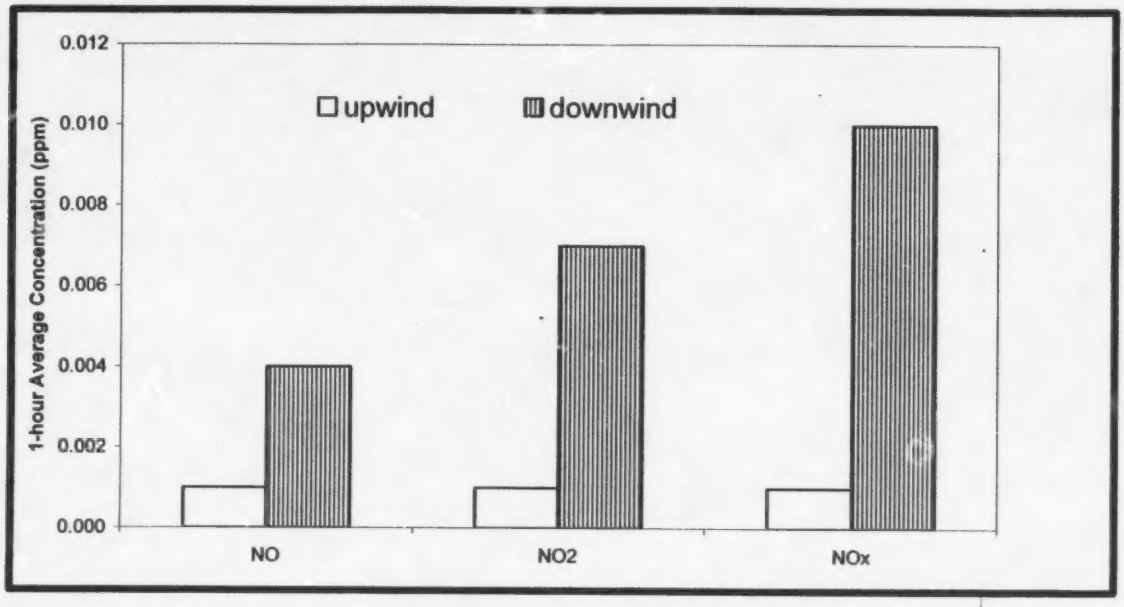

Figure 5: Oxides of nitrogen concentrations upwind and downwind of Hardisty Caverns Ltd.

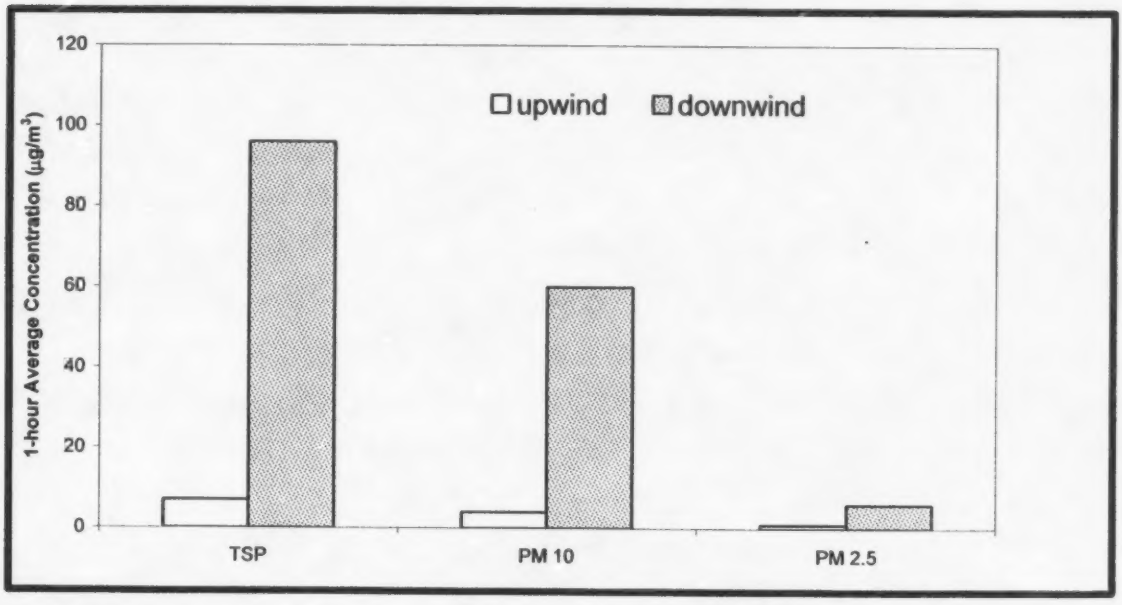

Figure 6: Particulate matter concentrations upwind and downwind of Hardisty Caverns Ltd.

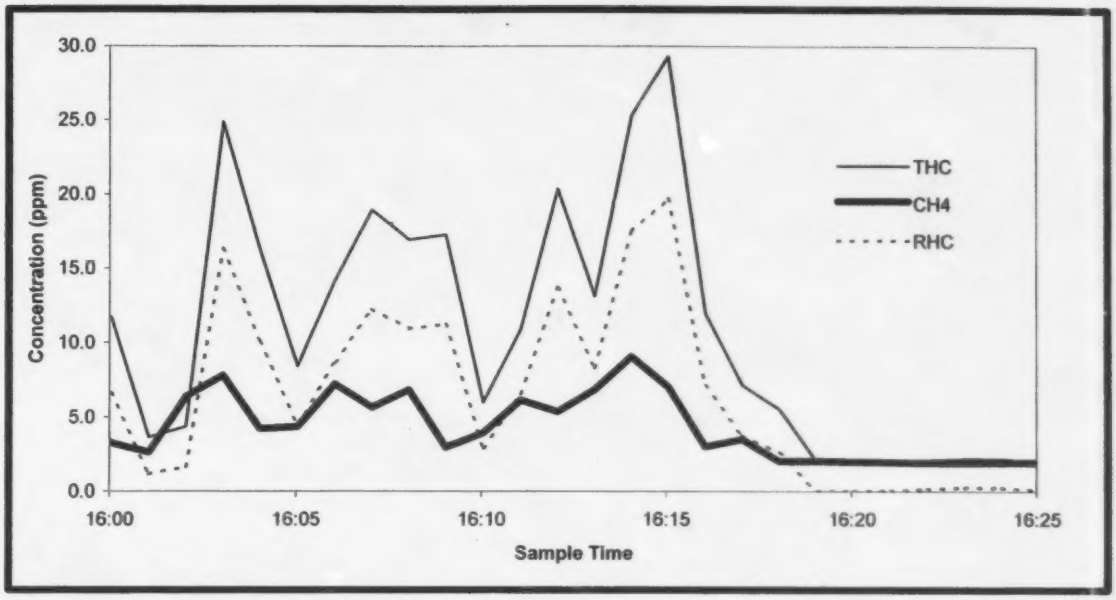

Figure 7: <u>One-minute</u> average hydrocarbon concentrations observed during a segment of the downwind sample hour at Site 2 (Hardisty Caverns).

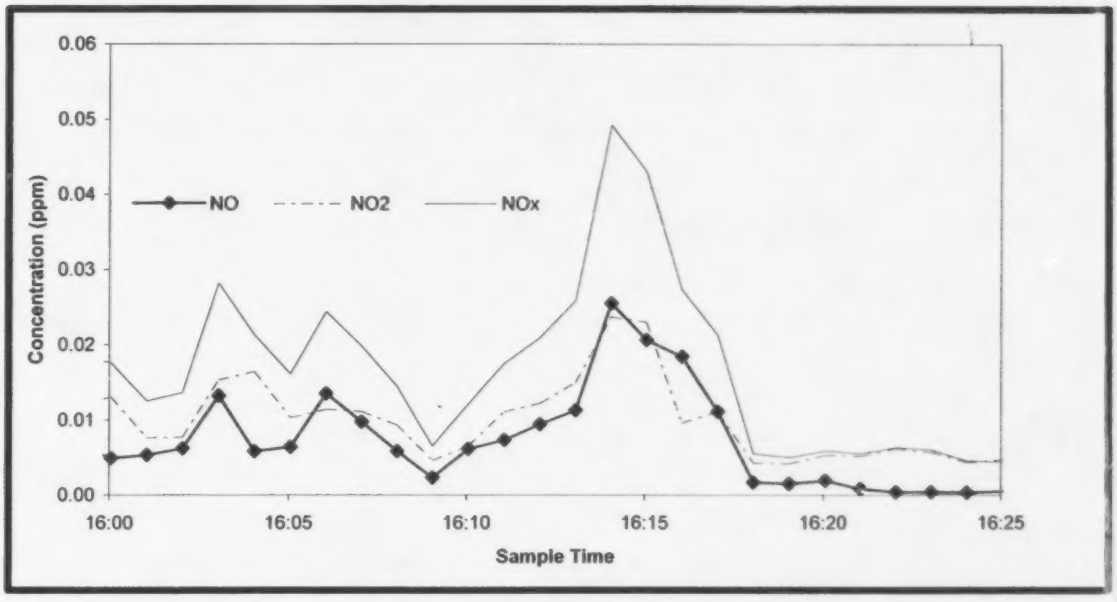

Figure 8: <u>One-minute</u> average oxides of nitrogen concentrations observed during a segment of the downwind sample hour at Site 2 (Hardisty Caverns).

Apache Canada Limited, Battle River Sour Gas Plant

The objective of the air quality survey downwind of Apache Canada Limited was to compare sulphur compounds measured in the fall with concentrations measured in the spring. Previous sampling in the area had shown an increase in sulphur compounds in the spring. Although increases in sulphur concentrations may have contributions from natural emissions, Apache Canada Limited reported stack releases of 129 tonnes of sulphur dioxide (SO_2) in 2005; preliminary data also indicates that this value increased to 389 tonnes in 2006[4]. Air quality data downwind of the Apache Canada was collected for *three hours*: One hour in the fall and two hours in the spring. The sulphur compounds monitored were total reduced sulphur (TRS), hydrogen sulphide (H_2S) and sulphur dioxide (SO_2). Potential sources for these compounds are discussed in Appendix B. The sample locations are indicated in Figure 2. The predominant wind direction for the spring sample had changed from west-northwest (WNW) in the fall to east-southeast (ESE). As a result the sample location was relocated to a site northwest of the Apache facility (**Site 3b**).

Air pollutant concentrations in the fall were typical of that measured in rural environments (Table 3). Relative to the one-hour average SO_2 concentrations in the Fall (0.001 ppm), a moderate increase in SO_2 was observed for both sample hours in the spring. One-hour average concentrations for the two spring sample hours were 0.006 and 0.004 ppm. These values are notably lower than the one-hour air quality objective of 0.172 ppm.

Increase in TRS concentration was only observed during the second sample hour in the spring, at which time one-hour average TRS concentration was 0.008 ppm. One-hour average TRS concentration for the fall sample was 0.001. TRS refers to a group of reduced sulphur compounds including hydrogen sulphide (H_2S) and organic sulphurs. For the spring sample, TRS was almost entirely composed of H_2S. Alberta has a one-hour an ambient air quality objective for H_2S of 0.010 ppm. The maximum one-hour average H_2S concentration in the spring was 80% of the AAAQO.

A closer examination of the spring samples revealed that elevated SO_2 and H_2S concentrations did not occur simultaneously. Sour gas plants such as Apache Canada can be a source of H_2S, however sulphur emissions from such facilities are typically oxidized to SO_2 prior

[4] National pollution release inventory (NPRI) http://www.ec.gc.ca/pdb/npri/npri_online_data_e.cfm

to release. Figure 9 illustrates the one-minute average concentration for a segment of the spring sample. The increase in TRS was accompanied by a reduction in SO_2 levels. During this transition there were no noteworthy changes in the meteorological conditions; the wind direction remained from the ESE with an average wind speed of 34 km/hr (Table A2). With the exception of a small increase in methane (CH_4) accompanying the increase in H_2S (Figure 9), there were no other notable changes in pollutant concentrations. The observed variation in pollutant concentrations is likely due to changes in industrial activity and/or emissions.

Table 3: One-hour average concentration measured downwind of Apache Canada Ltd..

Pollutant	Unit	Fall	Spring		AAAQO
			Hour 1	Hour 2	
CO	PPM	0.1	0.1	bd	13.0
O_3	PPM	0.033	0.038	0.038	0.082
THC	PPM	1.9	2.2	2.2	n/a
CH_4	PPM	2	2.2	2.3	n/a
RHC	PPM	bd	bd	bd	n/a
SO_2	PPM	0.001	***0.006***	***0.004***	0.172
NO	PPM	bd	0.001	0.001	n/a
NO_2	PPM	0.002	0.002	0.002	0.212
NOx	PPM	0.002	0.005	0.003	n/a
NH_3	PPM	bd	bd	bd	2.0
TRS	PPM	0.001	bd	***0.008***	n/a
H_2S	PPM	bd	bd	***0.008***	0.010
TSP	$\mu g/m^3$	16	4	6	n/a
PM_{10}	$\mu g/m^3$	9	3	4	n/a
$PM_{2.5}$	$\mu g/m^3$	1	1	1	n/a
PAH	ng/m^3	bd	bd	bd	n/a

Note: ***Bold and Italic*** indicates a notable increase during the spring sample

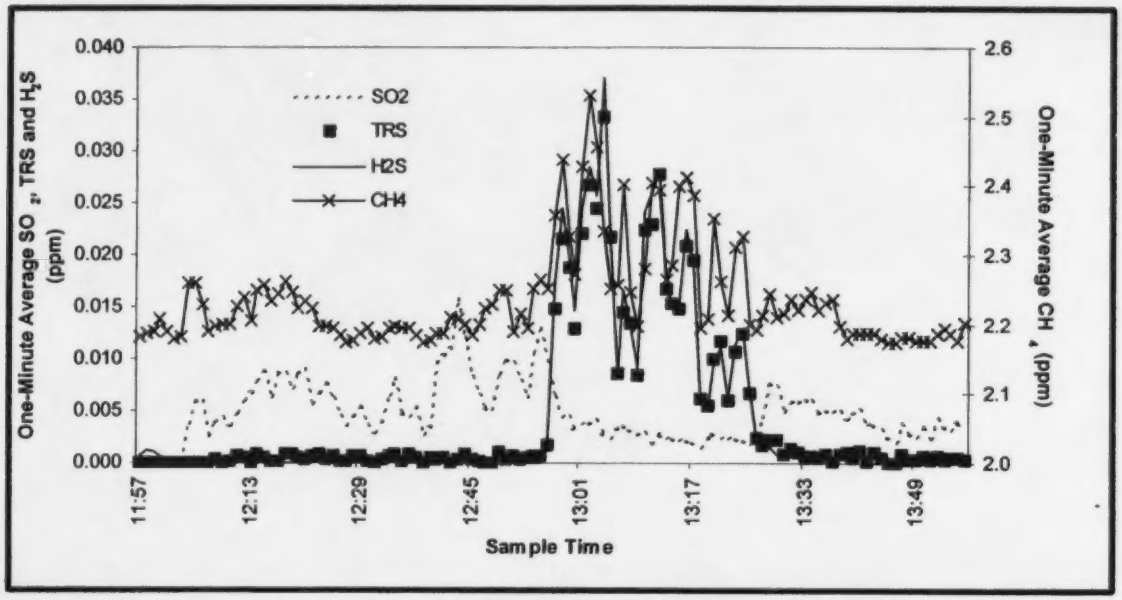

Figure 9: Variation in the concentrations of sulphur compounds downwind of Apache Canada Ltd.. Note that the left y-axis indicates concentration of sulphur compounds and the right y-axis indicates CH_4 concentrations.

Signalta Resources Limited, Forestburg Sour Gas Plant

Monitoring downwind of Signalta Forestburg was preformed for one hour during the fall. The location of the sample (**Site 4**) is shown in Figure 3. At the time, the wind speed was low (<7.5 km/hr), hampering the dispersion of emitted pollutants. One-hour average concentrations for **Site 4** are presented in Table 4. With the exception of SO_2 and NO_x (NO and NO_2), concentrations measured were typical for a rural environment. SO_2 concentration of 0.089 ppm was one of the highest measured for recent MAML surveys (Table A3). Figure 10 illustrates that within the hour of measurement, SO_2 and NO_x concentrations were variable and can at times have short term concentration notably above the one-hour average concentration. Although elevated, the one-hour SO_2 concentration did not exceed Alberta's ambient objective of 0.172 ppm. Alberta does not have an objective for NO, but has a one-hour objective for NO_2. During this monitoring event, the one-hour NO_2 objective was not exceeded.

Table 4: One-hour average concentration measured downwind of Signalta Resources Ltd.

Pollutant	*Units*	*One-hour average*	*AAAQO*
CO	PPM	0.2	*13*
O_3	PPM	0.024	*0.082*
THC	PPM	2.3	*n/a*
CH_4	PPM	2.3	*n/a*
RHC	PPM	bd	*n/a*
SO_2	PPM	0.089	*0.172*
NO	PPM	0.007	*n/a*
NO_2	PPM	0.008	*0.212*
NO_x	PPM	0.014	*n/a*
NH_3	PPM	bd	*2*
TRS	PPM	0.001	*n/a*
H_2S	PPM	0.001	*0.010*
TSP	$\mu g/m^3$	41	*n/a*
PM_{10}	$\mu g/m^3$	28	*n/a*
$PM_{2.5}$	$\mu g/m^3$	4	*n/a*
PAH	ng/m^3	1	*n/a*

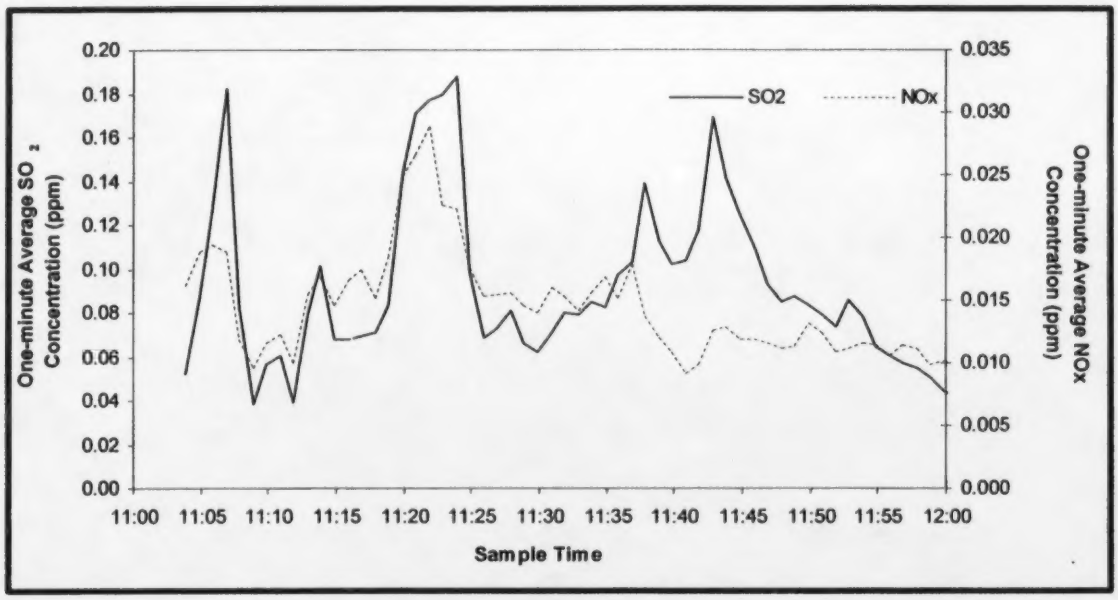

Figure 10: <u>One-minute</u> average sulphur dioxide (left y-axis) and oxides of nitrogen (right y-axis) concentrations measured downwind of Signalta Resources Ltd..

Appendix A

Table A1: One-hour average concentration sorted by monitoring location.

Site	Date	Start-End Times	CO PPM	O_3 PPM	THC PPM	CH_4 PPM	RHC PPM	SO_2 PPM	NO PPM	NO_2 PPM	NO_x PPM	NH_3 PPM	TRS PPM	H_2S PPM	TSP $\mu g/m^3$	PM_{10} $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	PAH ng/m^3
Hardisty Terminal Area																		
1	19-Oct-05	11:13 to 12:13	0.1	0.032	2.1	2.0	0.2	0.002	0.001	0.002	0.003	bd	0.001	0.001	15	10	1	bd
1	19-Oct-05	12:13 to 13:13	0.1	0.034	2.1	2.0	0.1	0.002	0.001	0.002	0.002	bd	0.001	bd	22	14	2	bd
1	19-Oct-05	13:13 to 14:13	0.1	0.032	2.1	2.0	0.1	0.001	0.001	0.002	0.002	bd	0.001	bd	23	15	2	bd
1	19-Oct-05	14:47 to 15:47	0.1	0.031	1.9	2.0	bd	bd	0.001	0.003	0.003	bd	bd	bd	80	49	5	bd
1a	20-Oct-05	11:37 to 12:37	0.1	0.034	2.0	2.0	bd	0.001	0.002	0.002	0.004	bd	0.001	bd	9	6	2	1
2	19-Oct-05	15:56 to 16:56	0.1	0.023	6.1	3.1	3.1	0.001	0.004	0.007	0.010	0.001	bd	bd	96	60	6	2
2a	20-Oct-05	12:44 to 13:26	bd	0.035	2.0	2.0	bd	bd	0.001	0.001	0.001	bd	bd	bd	7	4	1	bd
Appache Canada																		
3a	20-Oct-05	14:36 to 15:36	0.1	0.033	1.9	2.0	bd	0.001	bd	0.002	0.002	bd	0.001	bd	16	9	1	bd
3b	17-Mar-05	11:56 to 12:56	0.1	0.038	2.2	2.2	bd	0.006	0.001	0.002	0.005	bd	bd	bd	4	3	1	bd
3b	17-Mar-05	12:56 to 13:56	bd	0.038	2.2	2.3	bd	0.004	0.001	0.002	0.003	bd	0.008	0.008	6	4	1	bd
Signalta Resources																		
4	21-Oct-05	11:02 to 12:02	0.2	0.024	2.3	2.3	bd	0.089	0.007	0.008	0.014	bd	0.001	0.001	41	28	4	1

Notes:
ppm - parts per million **ng/m^3** = nanograms per cubic metre **$\mu g/m^3$** = micrograms per cubic meter **bd** – below detection limit of analyzer

Table A2: MAML operator's comments and meteorological conditions

Site	Date	Start/End Times	MAML Operator's Comments	Temp °C	RH %	WSP KPH	WDR
Hardisty Terminal Area							
1	19-Oct-05	11:13 to 12:13	Stopped 200 m south of Hwy 13 on RR 95 at the NW end of Husky Oil. This location is downwind of Husky, Express Pipeline pump terminal, Cold Lake Pipeline facility, and Gibson Meter stations.	13.3	54.4	16.5	SE
1	19-Oct-05	12:13 to 13:13	Same as at 11:13 am	14.8	49.3	17.3	SE
1	19-Oct-05	13:13 to 14:13	Same as at 11:13 am	14.3	53.3	17.5	SE
1	19-Oct-05	14:47 to 15:47	Stopped RR 95 on west side of road.	14.8	54.3	13.7	SSE
1a	20-Oct-05	11:37 to 12:37	Stopped 650m east of RR 95 on TwR 424 at the terminal facility	7.7	56.2	24.7	NNW
2	19-Oct-05	15:56 to 16:56	Stopped on North of Hwy 13 on RR 100 downwind of Hardisty Caverns. Trucks loading/unloading on site.	13.7	59.1	8.8	SE
2a	20-Oct-05	12:44 to 13:26	Stopped on North side of Hwy 13 on RR 100 upwind of Hardisty Caverns.	9.9	45.0	23.6	NW
Appache Canada							
3	20-Oct-05	14:36 to 15:36	Stopped at corner of RR 101 and TwR 390, small amounts of SO_2	8.3	44.4	21.9	WNW
3	17-Mar-05	11:56 to 12:56	Stopped about 1.6 km north of TwR 390, 700 m west of stack, pump station is located 290 m east of the MAML	-3.9	87.9	34.1	ESE
3	17-Mar-05	12:56 to 13:56	Same as 11:56	-3.5	88.0	34.1	ESE
Signalta Resources							
4	21-Oct-05	11:02 to 12:02	Stopped 600 m south of TwR 424 on Range Rd 161. About 2.5 km downwind of stack. Lots of farmers combining in the area.	8.7	56.3	4.0	SW

Notes:
Hwy – highway RR – Range road **TwR** – Township road
Temp – Temperature in degrees Celsius **RH** – relative humidity **WSP**- wind speed in km/hr **WDR** – Wind direction

Table A3: Median one-hour concentrations Alberta. Median concentrations were calculated for the periods indicated.

Station or Survey Type	Air Quality Station or Survey Name	Monitoring Period	CO ppm	O_3 ppm	THC ppm	CH_4 ppm	RHC ppm	SO_2 ppm	NO_2 ppm	NH_3 ppm	TRS ppm	H_2S ppm	TSP $\mu g/m^3$	PM_{10} $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	PAH ng/m^3
Mobile	Slave Lake	Dec 2005 -Mar 2006	0.2	0.003	2.4	2.4	bd	0.001	0.012	bd	0.001	bd	18	13	5	8
	Calder Yards Edmonton	Feb, Sept, Aug 2004 & Feb, Mar 2005	0.7	0.010	2.7	2.5	0.3	0.002	0.033	0.008	0.001	0.001	43	28	4	20
	Tolko High Prairie	Dec 2005 -Mar 2006	0.2	0.018	2.0	1.9	bd	0.001	0.005	bd	0.001	bd	18	12	3	2
	Caroline	Oct 05 & Jan, May, Jun 06	0.2	0.038	1.8	1.8	bd	0.002	0.004	0.003	0.001	0.001	79	49	6	1
	Girouxville	Fall 2004, spring 2005, 2006	0.3	0.028	2.1	2.1	bd	0.001	0.001	0.013	0.002	0.001	21	15	2	bd
	Whitecourt	Sep. 6 - 7, 2005	0.2	0.03	2.1	2.1	bd	0.001	0.002	0.084	0.001	0.001	28	16	2	1
Permanent Continuous Monitoring Stations																
Urban	Calgary Central[1]	Oct 05 & Mar 06	0.4	0.010	2.1	n/a	n/a	n/a	0.026	n/a	n/a	n/a	n/a	19	6	n/a
	Edmonton Central[1]	Oct 05 & Mar 06	0.4	0.016	2.1	n/a	n/a	n/a	0.025	n/a	n/a	n/a	n/a	n/a	5	n/a
Small Urban	Red Deer (Riverside)[2]	Oct 05 & Mar 06	0.3	0.027	2.0	n/a	n/a	bd	0.010	n/a	n/a	bd	n/a	4	2	n/a
Rural	Caroline [2]	Oct 05 & Mar 06	n/a	0.035	2.2	n/a	n/a	bd	0.003	n/a	bd	n/a	n/a	n/a	n/a	n/a
Industrial	Mannix[2]	Oct 05 & Mar 06	n/a	n/a	2	n/a	n/a	0.001	n/a	n/a	n/a	bd	n/a	n/a	n/a	n/a

Notes:
ppm - parts per million **ng/m^3** = nanograms per cubic metre **$\mu g/m^3$** = micrograms per cubic meter **bd** – below detection limit of analyzer **n/a** – data not available
1- station operated by Alberta Environment
2- station operated by Airsheds

Appendix B

A glossary of pollutants monitored by the MAML

Ammonia (NH_3)

Ammonia (NH_3) is a colourless gas with a well-known pungent odour. Some natural sources of NH_3 include the decay of plant material and animal waste. In Alberta, commercial feedlots, specifically from their large amounts of decaying animal wastes and the fertilizer industry is the main industrial source of NH_3.

Carbon Monoxide (CO)

Carbon monoxide (CO) is emitted into the atmosphere primarily from incomplete combustion of fuels such as gasoline, oil and wood. Sources of CO include motor vehicles, fireplaces, industry, and natural gas combustion and forest fires.

Total Hydrocarbons (THC)

The term "total hydrocarbons" (THC) refers to a broad family of chemicals that contain carbon and hydrogen atoms. Methane (CH_4), a non-reactive hydrocarbon, is the most common hydrocarbon in the earth's atmosphere. As a result, for most measurements around Alberta, concentrations of THC and CH_4 are equivalent and a background concentration of about 2 ppm is typically measured. Reactive hydrocarbons (RHC) form the remaining fraction of THC. RHC are important because: (1) they can react with oxides of nitrogen in the presence of sunlight to form ozone; and (2) some RHC can be toxic (at high concentrations) to humans, animals or vegetation. The major sources of hydrocarbons include vegetation, vehicle emissions, gasoline marketing and storage tanks, petroleum and chemical industries and fugitive emissions such as leaks and evaporation of solvents.

Oxides of Nitrogen (NO, NO_2 and NO_x)

The sum of nitrogen dioxide (NO_2) and nitric oxide (NO) is known as oxides of nitrogen (NO_x). During high temperature combustion as in the burning of natural gas, coal, oil and gasoline, atmospheric nitrogen (N_2) may combine with molecular oxygen (O_2) to form two molecules of NO. In the atmosphere, NO will readily react with ozone (O_3) to form NO_2. NO_2 is a reddish-brown gas and is partially responsible for the "brown haze" observed near large

cities. In Alberta, transportation is the major source of NO_x. These include automobiles, locomotives and aeroplanes.

Particulate Matter (TSP, PM_{10} and $PM_{2.5}$)

Inhalable particulates are particulate matter less than 10 micrometres in aerodynamic diameter (PM_{10}). Sources of PM_{10} include soil dust, road dust, agricultural dust, smoke from forest fires and wood burning, vehicle exhaust and industrial emissions. Respirable particulates are particulate matter less than 2.5 micrometres in aerodynamic diameter ($PM_{2.5}$). $PM_{2.5}$ are small enough to penetrate into the lungs. Respirable particulates may form in the atmosphere and/or arise from combustion sources such as vehicle exhaust, industrial emissions and wood burning. Total suspended particles (TSP) range in size from 0.001 to 500 micrometer; this group includes both PM_{10} and $PM_{2.5}$.

Polycyclic aromatic hydrocarbon (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are formed through incomplete combustion and consist of two or more benzene rings. Vehicle exhaust, wood smoke from residential use, industrial use and forest fires are all sources of PAHs. PAHs can be found as a gas or condensed onto particles. Larger PAHs (containing more benzene rings) tend to attach onto particles. ***It is these types of PAHs that are measured by the MAML.*** Particle PAHs have been associated with soot from diesel combustion. There are more than 100 different PAHs with varying levels of toxicity. PAHs usually occur as complex mixtures rather than single compounds.

Sulphur Dioxide (SO_2)

In Alberta, natural gas processing plants are responsible for close to half of the sulphur dioxide (SO_2) emissions in the province. Other sources include gas plant flares, oil sands facilities, oil refineries, pulp and paper mills and fertilizer plants. SO_2 can also be produced during the combustion of sulphur containing fuels such as coal and oil. Coal fired power plants and diesel powered transportations such as trucks, locomotives and marine vessels can be SO_2 sources.

Total Reduced Sulphur (TRS) Including Hydrogen Sulphide (H_2S)

Total reduced sulphur includes hydrogen sulphide (H_2S), mercaptans, dimethyl sulphide, dimethyl disulphide, and other sulphur compounds. The major industrial sources of H_2S and

TRS are fugitive emissions from petroleum refineries, tank farms for unrefined petroleum products, natural gas plants, petrochemical plants, oil sands plants, sewage treatment facilities, pulp and paper plants that use the Kraft pulping process, and animal feedlots. Natural sources of H_2S include sulphur hot springs, sloughs, swamps and lakes.

Alberta's Ambient Air Quality Objectives

Alberta's Ambient Air Quality Objectives[1] are established under Section 14 of the Environmental Protection and Enhancement Act (EPEA , R.S.A. 2000, c.E-12, as amended). EPEA provides for the development of environmental objectives for Alberta.
The Ambient Air Quality Objectives are used for:

- Reporting on the state of the atmospheric environment in Alberta.
- Reporting to Albertans on the quality of the air through Alberta's Air Quality Index (AQI).
- Establishing approval conditions for regulated industrial facilities.
- Evaluating proposals to construct facilities that will have air emissions.
- Guiding special ambient air quality surveys.
- Assessing compliance near major industrial air emission sources.

Some of Alberta's Ambient Air Quality Objectives are based on odour perception. This is the case for ammonia, nitrogen dioxide and hydrogen sulphide. For these chemicals, people are likely to detect an odour at concentrations well below levels that may affect human health. Alberta's Ambient Air Quality Objectives for one-hour average concentration of pollutants monitored by the MAML are listed in Table B1.

Table B1: Alberta's Ambient Air Quality Objective measured by the MAML

Pollutant	One-hour AAAQO (ppm*)	Basis for Objective
Ammonia	2	odour perception
Carbon monoxide	13	oxygen carrying capacity of blood
Nitrogen dioxide	0.212	odour perception
Ozone	0.082	reduction of lung function and effects on vegetation
Hydrogen sulphide	0.01	odour perception
Sulphur dioxide	0.172	pulmonary function

* parts per million

[1] *Alberta Ambient Air Quality Objectives*. Alberta Environment. April 2005.

TRS are fugitive emissions from petroleum refineries, tank farms for unrefined petroleum products, natural gas plants, petrochemical plants, oil sands plants, sewage treatment facilities, pulp and paper plants that use the Kraft pulping process, and animal feedlots. Natural sources of H_2S include sulphur hot springs, sloughs, swamps and lakes.

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The Mobile Air Monitoring Laboratory (MAML)

The MAML is a 27-foot (8.2 m) vehicle that has been specially designed and equipped to measure air quality. It houses a variety of instruments that continuously sample the air at specified time or distance intervals. The MAML is equipped with:

- a dual computer system custom-programmed to accept and record the measurement of air samples from each analyser,
- a GPS (Global Positioning System) that identifies the MAML's location as it moves around Alberta,
- an exhaust purifying system that minimizes emissions from the vehicle and
- two on-board generators that are also equipped with exhaust scrubbers

Table B2 lists the pollutants and meteorological data monitored by the MAML. Also indicated are the lower and upper detection limits for each monitored species.

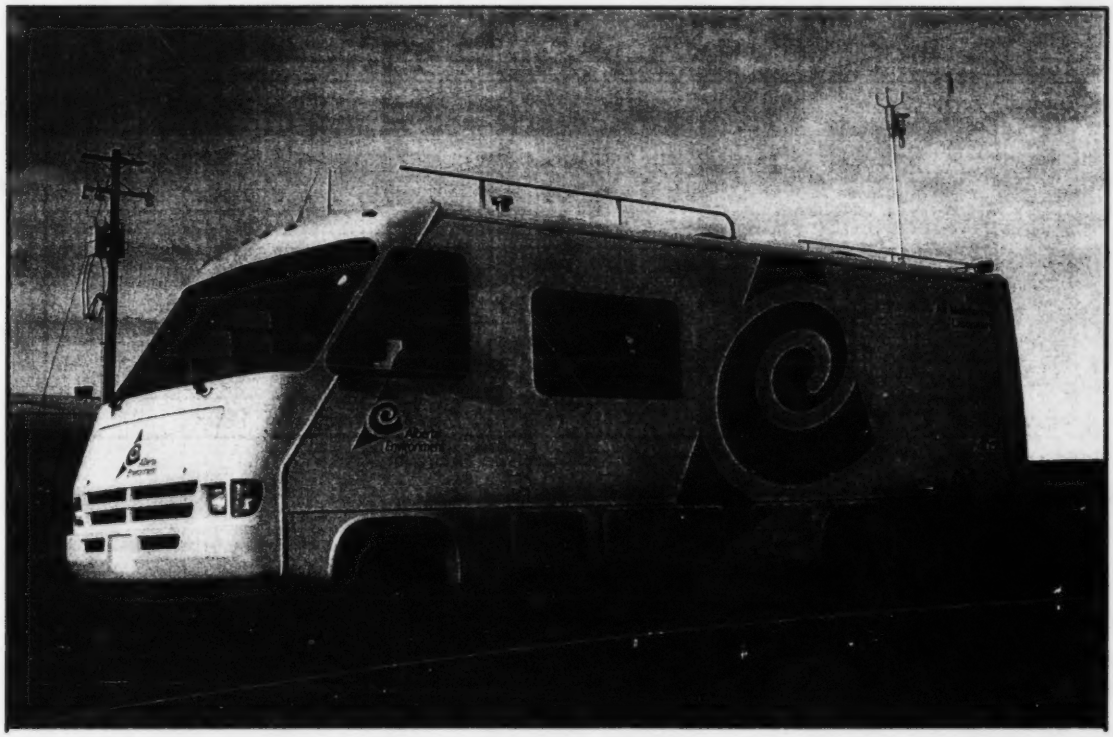

Figure B1: Alberta Environment's Mobile Air Monitoring Laboratory

Table B2: Pollutants and meteorological data monitoring by the MAML.

	Lower Detection Limit*	Upper Detection Limit**
	0.001 ppm	5 ppm
	0.001 ppm	0.5 ppm
	0.1 ppm	50 ppm
	0.1 ppm	20 ppm
	0.1 ppm	20 ppm
	0.1 ppm	20 ppm
	3 ng/m^3	1000 ng/m^3
	0.0006 ppm	1 ppm
	0.0006 ppm	1 ppm
	0.0006 ppm	1 ppm
	1 $\mu g/m^3$	1.0 g/m^3
	1 $\mu g/m^3$	1.0 g/m^3
	1 $\mu g/m^3$	1.0 g/m^3
	0.001 ppm	1 ppm
	0.001 ppm	1 ppm
	0.001 ppm	2 ppm
	0 km/hr	200 km/hr
	0 degrees	360 degrees
	-40 °C	50 °C
	0%	100%

ppm - parts per million

ng/m^3 = nanograms per meter cubed

$\mu g/m^3$ = micrograms per meter cubed

g/m^3 = grams per meter cubed

* The ***lower detection limit*** indicates the *minimum* amount of pollutant and the lower limit of meteorological data can be measured by the instrument.

** The ***upper detection limit*** indicates the *maximum* amount of pollutant the instrument can detect and the upper limit for meteorological data measured. This limit is set to provide the optimum precision over that range. The upper limit can be raised, however, precision at the lower levels (where most levels are monitored) is then compromised.

Table B2: Pollutants and meteorological data monitoring by the MAML.

Pollutant	Operating Range	
	Lower Detection Limit*	Upper Detection Limit**
Ammonia (NH_3)	0.001 ppm	5 ppm
Ozone (O_3)	0.001 ppm	0.5 ppm
Carbon Monoxide (CO)	0.1 ppm	50 ppm
Hydrocarbons		
Methane (CH_4)	0.1 ppm	20 ppm
Reactive Hydrocarbons (RHC)	0.1 ppm	20 ppm
Total Hydrocarbons (THC)	0.1 ppm	20 ppm
Polycyclic Aromatic Hydrocarbons (PAH)	3 ng/m^3	1000 ng/m^3
Oxides of nitrogen		
Nitrogen dioxide (NO_2)	0.0006 ppm	1 ppm
Nitric Oxide (NO)	0.0006 ppm	1 ppm
Oxides of nitrogen (NO_x)	0.0006 ppm	1 ppm
Particulate Matter		
Total Suspended Particulates (TSP)	1 $\mu g/m^3$	1.0 g/m^3
Particulate Matter <10μm (PM_{10})	1 $\mu g/m^3$	1.0 g/m^3
Particulate Matter <2.5μm ($PM_{2.5}$)	1 $\mu g/m^3$	1.0 g/m^3
Sulphur Compounds		
Hydrogen Sulphide (H_2S)	0.001 ppm	1 ppm
Total Reduced Sulphur (TRS)	0.001 ppm	1 ppm
Sulphur Dioxide (SO_2)	0.001 ppm	2 ppm
Meteorological data		
Wind Speed	0 km/hr	200 km/hr
Wind Direction	0 degrees	360 degrees
Temperature	-40 °C	50 °C
Relative humidity	0%	100%

ppm = parts per million

ng/m^3 = nanograms per meter cubed

$\mu g/m^3$ = micrograms per meter cubed

g/m^3 = grams per meter cubed

* The ***lower detection limit*** indicates the *minimum* amount of pollutant and the lower limit of meteorological data can be measured by the instrument.

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